

Global warming and the breeding birds of the Arctic

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SUMMARY.—The purpose of this paper is to outline some of the effects of global warming on Arctic habitats, to summarise some of the definitions of the Arctic that have been used in the past, to propose a tight definition of the area that would facilitate monitoring, and to provide a list of the breeding species of the area so defined. It is not intended to discuss the effects of global warming on individual species or populations, or to attempt to summarise the huge volume of ongoing research on climate change. It is recognised that any definition of the Arctic is open to criticism, but general agreement is a prerequisite for effective monitoring of the changes caused by global warming.

There are now very few scientists involved in climate change research who do not agree that marked global warming is occurring and is a serious issue, although opinions differ on the precise extent to which sea levels will rise and global temperatures increase. This is because different computer models give different results, and predictions are constantly changing as more data become available. The publication of ACIA (2004) presented the results of an assessment made by nearly 300 scientists, based not on worst-case scenarios but on observed changes by 2004, combined with projected temperature increases *below* the mid-range of those anticipated by increasingly accurate global climate models. These predictions have serious ecological implications. The Arctic is experiencing some of the most rapid and severe climate changes on the planet, and these are projected to increase substantially in the future. It is clear that many bird species currently breeding at northern latitudes will be affected by predicted changes, and it is essential that the situation be closely monitored. Publications that have been referred to include Zockler & Lysenko (2000), which was one of the first to closely examine the impact of climate change on Arctic breeding waterbirds, and ACIA (2004), which looks in detail at the impacts of global warming on the Arctic.

The effects of global warming

The ACIA report suggests that at least 50% of summer sea-ice in the Arctic will melt by 2099, along with a significant portion of the Greenland ice sheet, as the region is projected to warm by 4–7°C (other models predict 5–8°C) by the year 2100. Greenland could produce sufficient meltwater to eventually raise sea levels by *c.*7 m. Over the past 30 years the mean extent of sea-ice has decreased by *c.*8% and late summer ice coverage by 15–20%. In September 2002 the smallest extent of Arctic sea-ice cover on record was noted. More recently IPCC (2007) showed that in 2007 even less ice was recorded. This report states that satellite data since 1978 reveal that annual mean Arctic sea-ice extent has shrunk by 2.7% (2.1–3.3%) per decade, with larger decreases in summer of 7.4% (5.0–9.8%) per decade. In December 2006, the University Corporation for Atmospheric Research in the USA predicted that if greenhouse gases continue to build up in the atmosphere at the current rate, then by 2040 only a small amount of perennial sea-ice will remain along the north coasts of Greenland and Canada, and most of the Arctic basin will be ice-free in September. In 2008 the extent of the sea-ice was the lowest recorded since records began. Mean Arctic temper-

atures have increased at almost twice the global rate in the last 100 years. Should the Arctic Ocean become completely ice-free in summer, which some models predict, then the ecological consequences could be devastating. It was shown by ACIA (2004) that snow cover over Arctic land areas has declined by *c.*10% over the last 30 years or so, and it has been projected that it will decrease by an additional 10–20% by 2100. Recent decades have also seen widespread glacier melt, rising permafrost temperatures and increased coastal erosion. Reductions in sea-ice will drastically reduce the marine habitat for Polar Bears *Ursus maritimus*, ice-inhabiting seals and some seabirds.

In a region as large and diverse as the Arctic, the effects of global warming will not be uniform, because there are significant subregional variations in climate and recent warming has been more dramatic in some areas than in others. Generally, the treeline will move northwards and to higher elevations, with forest and shrubland replacing a significant proportion of the existing tundra habitats as the permafrost thaws, and tundra vegetation will shift north into polar desert habitat, which may be considerably reduced in extent or even eliminated. Existing forest-tundra habitats (in Canada and Russia) are likely to become more forested and thus less suitable for some species. These changes will result in northward shifts in the ranges of plant and animal species, and some might well become extinct. One region where biological diversity will be most at risk is Chukotka, northern Alaska and the western Canadian Arctic, which currently holds the largest number of threatened plant and animal species of any other arctic subregion, including >70% of rare Arctic plant species (ACIA 2004). As a result of these changes, Arctic biomes will be among the most severely affected by a warming climate, and will be among the first to show direct impacts. According to previous records in the Quaternary, large forest shifts of up to 2,000 km have been recorded. Deglaciation caused an average migration (even of long-lived trees) of 200–500 m/p.a. in response to rapid environmental changes, and such rates were sustained for several millennia (Huntley 1996).

It was suggested by Maddox (1996) that one region, extending from the north-east Canadian archipelago and west Greenland to Iceland, would experience lower temperatures at all seasons, a phenomenon caused by the strengthening of the Icelandic low to the south-east, resulting in increased north to north-westerly flow over this area. However, the IPCC (2007) report predicted a negative mass balance for the Greenland ice sheet, which is not consistent with a lower temperature. Should severe cooling occur it would adversely impact the breeding population of Greenland White-fronted Geese *Anser albifrons flavirostris*.

Species ranges are projected to shift north on both land and at sea, thereby bringing 'new' species into the Arctic whilst severely limiting the available suitable habitat to other species that are currently present. Some seabirds such as Ivory Gull *Pagophila eburnea* and Little Auk *Alle alle* are highly likely to be negatively affected by the decline in the extent of sea-ice and subsequent changes to the communities in which they live. *P. eburnea* is intimately associated with sea-ice during most of its life cycle. There is a complex interaction of factors that complicates predictions of the impacts of climate change on Arctic waterbirds. Species will not react statically to climate change and will certainly respond to changing habitats. Many will be able to extend their range with the northward shift of their preferred habitat. Clearly there are limits and in particular those species breeding on the edge of their range in high-Arctic habitats will encounter increasingly less suitable conditions as the climate warms. Most *Calidris* shorebirds will be unable to adapt to shrubby or tree-like habitats and cannot expand into other habitats, except perhaps for a few areas gained by retreating glaciers. Useful recent studies of the effects of climate change on Arctic birds include those by Boyd & Diamond (1994), Boyd & Madsen (1997) and Bauer *et al.* (2008).

The Intergovernmental Panel on Climate Change (IPCC 1998) predicted a major change in Arctic vegetation types, including a decrease of 40–57% of the area currently covered by tundra vegetation. Tundra is the most relevant biome for Arctic waterbirds, hence there are major implications for their populations. A possible scenario of changes to tundra habitat as predicted due to CO₂ doubling during the period 2070–99 indicates the possible extent of habitat loss for a range of species. The tundra-breeding Bean Geese *Anser fabalis rossicus* / *A. f. serrirostris* could lose 76% of their present tundra habitat. Comparable figures for other species include Red-breasted Goose *Branta ruficollis* 67%, Ross's Gull *Rhodostethia rosea* 54% and Red-necked Stint *Calidris ruficollis* 48%. Other tundra-nesting taxa will also be affected. However, there are extensive unvegetated areas in the Arctic at high elevations that may become suitable habitat for tundra-nesting species as the climate warms. Some tundra-nesting waders such as Great Knot *Calidris tenuirostris*, Baird's Sandpiper *C. bairdii* and Purple Sandpiper *C. maritima* are relatively scarce and nest at low densities. These may be able to withstand a substantial reduction in breeding habitat because that habitat is unsaturated at present.

Defining the Arctic

Global warming will bring changes to habitats and to bird populations currently breeding in the biome, and if these are to be accurately monitored then agreement regarding the boundary of the Arctic is essential. Whilst there has never been universal agreement on this point, the vast majority of ecologists and geographers have adopted the 10°C July isotherm as the southern boundary, as proposed by Koppen (1900), because this is closely correlated with the northern edge of the treeline (the northern limit of arborescent growth) or the northern limit of the boreal forest. However, the two lines do diverge, in places by up to c.160 km. Another important point relevant to this definition is that all of the areas included therein are underlain by continuous permafrost (see Fig. 5.2 in Sage 1986). Areas of continuous permafrost do, of course, occur south of the boundary proposed here.

The main disagreements revolve around whether or not Fennoscandia, Iceland, and sometimes the west coast of Alaska and the Aleutians should be included within the Arctic. Various authors have included all or some of these areas in their definition of the Arctic. For example, Stonehouse (1971) employed a wide definition that included most of Iceland, western Alaska south of Cape Prince of Wales, and various Bering Sea islands. A much tighter definition was adopted by Sage (1986) who excluded Iceland, Fennoscandia and, in Alaska, took the Continental Divide of the Brooks Range from Cape Lisburne east to the Canadian border as the southern limit. More recently Sale (2006), using a 'pragmatic approach', included Iceland but not Fennoscandia. In Canada he included the southern end of Hudson Bay, northern Quebec and Labrador. In Alaska he included the west coast (but little of the hinterland), the Pribilofs and Aleutians and, remarkably, Mount Denali (McKinley) National Park in the Alaska Range nearly 400 km south of the Arctic Circle. In Russia the Commander Islands, the Kamchatka Peninsula, and the north-east coast of the Sea of Okhotsk were all included.

The most extensive and confusing definition to be suggested to date is that of the CAFF (2001) report prepared for the Arctic Council. The CAFF boundary includes Iceland, much of mainland Scandinavia, and much of the hinterland of Russia, where it extends south of the July isotherm well into the boreal forest biome, but excludes Kamchatka and the Commander Islands. In Canada also it extends well below the July isotherm and into the boreal forest. In Alaska the boundary includes much of the south-west including the



Figure 1. The limits of the Arctic according to various definitions (from CAFF 2001).

Aleutian chain. In ecological terms the CAFF boundary is completely illogical. The position of the CAFF boundary, the 10°C July isotherm, and the treeline are all shown in Fig. 1.

In defining the Arctic the July isotherm cannot be followed in its entirety because, in Alaska, it turns south to touch the Aleutians, goes on through the Bering Sea to pass across Kamchatka, and in Canada loops down to the southern end of Hudson Bay and proceeds east to include part of the forest-tundra habitat of Labrador. A modification of the 10°C July isotherm was suggested by Nordenskjöld & Mecking (1928) to take account of the fact that the coldest point in the Northern Hemisphere lies in the Siberian boreal forest south of the isotherm. This modification has largely been ignored, except by Sale (2006).

There is strong rationale for not including certain areas within the true Arctic because most of them belong in the subarctic. In the case of Fennoscandia, because of the influence of the North Atlantic Drift, its climate, fauna and flora are all closer to those of the temperate zone, and what little permafrost is present is discontinuous. Iceland was excluded by Nordenskjöld & Mecking (1928) on the basis of their research into its climate and flora. The Aleutians have no permafrost and are barely touched by the July isotherm. The Kamchatka Peninsula lies in the boreal forest zone and is underlain only by discontinuous permafrost. In a quite recent paper on floristic divisions in the Arctic, Yurtsev (1994) quite specifically excluded the Aleutians, Commanders and Pribilofs, Iceland and northernmost Scandinavia because of the boreal-oceanic aspect to their floras, which is expressed by a high proportion of boreal, particularly boreal-oceanic, species and other oceanic hypo-arctic and low-arctic taxa alien to circumpolar areas.

Finally, mention must be made of the forest-tundra habitat, which is quite extensive in Canada, but in Russia is restricted to a relatively narrow belt up to 300 km wide (see Figs. 1.2 and 1.4 in Sage 1986). This habitat basically represents a zone of intergradation between the boreal forest and true tundra, and was assigned to the subarctic by Love (1970).

However, it was suggested by Rosseau (1952) that the forest-tundra is not a transitional habitat, but comprises purely arctic patches imprisoned within a network of subarctic forest strips. Insofar as birds are concerned, assigning the forest-tundra zone to the subarctic makes very little difference as it only excludes basically forest species that penetrate the forest-tundra, but do not usually reach the true tundra.

The variety of definitions mentioned above, no two of which are identical, illustrate the difficulty of monitoring changes in breeding bird populations. What is required for this purpose is a tight definition of the true Arctic, as opposed to the subarctic. It is suggested that the most practical definition of the true Arctic could be a modification of that used by Sage (1986), where the southern boundary in Alaska ran westwards from the Canadian border along the Continental Divide of the Brooks Range to Cape Lisburne (see Fig. 1.3 in Sage 1986). It is proposed that this boundary be amended to include the coastal highlands of rolling topography and gentle slopes, tundras, and plains and lowlands south from Cape Lisburne as far as and including the Seward Peninsula. The taiga habitat extends on to the south-eastern quarter of the peninsula, but this is excluded. The whole of this additional area is underlain by continuous permafrost (see Fig. 5.2 in Sage 1986). The forest-tundra zone in Canada is regarded as subarctic, leaving the extreme north of the Ungava Peninsula in the true Arctic. All of Greenland, along with Svalbard, is included. In Russia, as in Canada, the forest-tundra belt is considered as subarctic, whilst the polar desert and tundra biomes comprise the true Arctic. Also included therein are the tundra areas of the Chukotka Peninsula.

Breeding species of the true Arctic

A few workers have produced lists of Arctic breeding birds, e.g., Salomonsen (1972) who listed 141 species as breeding regularly in the region. In Sage (1986) 183 species were recognised including several of marginal occurrence. The differing totals are mainly due to slightly varying views regarding boundaries, and the availability of new information. A much higher total of 280 species was given in CAFF (2001). However, nowhere in this publication is a full list given, the appendix listing only those mentioned in the text. Furthermore, Surf-bird *Aphriza virgata* is shown as breeding entirely in the Arctic, yet its breeding range includes the Alaska Range and south to the Chugach Mountains, both outside even CAFF's wide definition of the Arctic. Earlier, Scott (1998) stated that of the 449 species of birds that breed or have bred (listed in Appendix 1) in the Arctic region, 279 breed in significant numbers within the Arctic, but nowhere is it explained what the difference is between 'the Arctic region' and 'the Arctic'. The list in Scott's Appendix 1 includes many species which have never previously been suggested as having any connection with the polar region, for example Eurasian Capercaillie *Tetrao urogallus*, Corncrake *Crex crex*, Black Woodpecker *Dryocopus martius* and Palm Warbler *Dendroica palmarum*. It also lists Water Rail *Rallus aquaticus* and Common Snipe *Gallinago gallinago* as having bred occasionally in Greenland. However, D. Boertmann (1994 and *in litt.* 2008) states that neither of these latter two species has ever bred there.

Within the true Arctic as defined above, 203 species are considered to have bred (Appendix 1). Order, taxonomy and names follow Gill & Wright (2006). In Collinson *et al.* (2008) American Herring Gull *Larus smithsonianus* is recognised as a species distinct from Herring Gull *L. argentatus*, but this split is not adopted here as it has not been accepted by the American Ornithologists' Union at the time of writing. Some species listed are of marginal occurrence in the Arctic or have very limited distributions, and these are identified in Appendix 1. Also shown are the number of breeding species in Alaska, Canada, Greenland,

Svalbard and Russia. Eskimo Curlew *Numenius borealis*, which formerly bred in northern Canada, has been omitted as it is probably extinct. Also omitted are Common Sandpiper *Actitis hypoleucos* and Brambling *Fringilla montifringilla*, which bred on the Yamal Peninsula, Russia, in 1950 during a period of climatic amelioration, but have not done so since (P. Tomkovich *in litt.* 1985). Whooper Swan *Cygnus cygnus* formerly bred in Greenland but no longer does so (Boertmann 1994), and Barn Swallow *Hirundo rustica* has bred once (possibly twice) on the Arctic Slope of Alaska (Pitelka 1974). Finally, Baikal Teal *Anas formosa*, which formerly bred on the northern Russian tundra and, in the early 20th century, as far north as Bolshoy Lyakhovsky Island, in the New Siberian Archipelago, is now a rare species and few breeding records are available, so it is excluded from the list (P. Tomkovich *in litt.* 2008).

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Appendix. Breeding birds of the Arctic

	Alaska	Canada	Greenland	Svalbard	Russia
Willow Ptarmigan <i>Lagopus lagopus</i>	x	x			x
Rock Ptarmigan <i>Lagopus mutus</i>	x	x	x	x	x
Bean Goose <i>Anser fabalis</i>					x
Pink-footed Goose <i>Anser brachyrhynchus</i>			x	x	
Greater White-fronted Goose <i>Anser albifrons</i>	x	x	x		x
Lesser White-fronted Goose <i>Anser erythropus</i>					x*(a)
Emperor Goose <i>Anser canagicus</i>	x				x*
Snow Goose <i>Chen caerulescens</i>	x	x	x		x
Ross's Goose <i>Chen rossii</i>		x			
Canada Goose <i>Branta canadensis</i>	x	x	x		
Cackling Goose <i>Branta hutchinsii</i>	x	x			
Brant Goose <i>Branta bernicla</i>	x	x	x	x	x
Barnacle Goose <i>Branta leucopsis</i>			x	x	x
Red-breasted Goose <i>Branta ruficollis</i>					x
Trumpeter Swan <i>Cygnus buccinator</i>	x	x			
Tundra Swan <i>Cygnus columbianus</i>	x	x	x		x
Whooper Swan <i>Cygnus cygnus</i>					x*
Eurasian Wigeon <i>Anas penelope</i>					x*(a)
American Wigeon <i>Anas americana</i>	x	?			
Mallard <i>Anas platyrhynchos</i>	x	x	x		
Northern Shoveler <i>Anas clypeata</i>	x	x			
Northern Pintail <i>Anas acuta</i>	x	x	x		x
Eurasian Teal <i>Anas crecca</i>	x	x	x		x
Redhead <i>Aythya americana</i>	x(d)				
Tufted Duck <i>Aythya fuligula</i>					x*©
Greater Scaup <i>Aythya marila</i>	x	x			x
Lesser Scaup <i>Aythya affinis</i>	x	x			
Steller's Eider <i>Polysticta stelleri</i>	x				x
Spectacled Eider <i>Somateria fischeri</i>	x				x
King Eider <i>Somateria spectabilis</i>		x	x	x	x
Common Eider <i>Somateria mollissima</i>	x	x	x	x	x
Harlequin Duck <i>Histrionicus histrionicus</i>	x	x	x		x
Surf Scoter <i>Melanitta perspicillata</i>	x	x			
Velvet Scoter <i>Melanitta fusca</i>					x
White-winged Scoter <i>Melanitta deglandi</i>	x	x			
Black Scoter <i>Melanitta nigra</i>					x
American Scoter <i>Melanitta americana</i>	x	x			
Long-tailed Duck <i>Clangula hyemalis</i>	x	x	x	x	x
Barrow's Goldeneye <i>Bucephala islandica</i>			x		

Red-breasted Merganser <i>Mergus serrator</i>	x	x	x		
Red-throated Loon <i>Gavia stellata</i>	x	x	x	x	x
Black-throated Loon <i>Gavia arctica</i>					x
Pacific Loon <i>Gavia pacifica</i>	x	x			x
Great Northern Loon <i>Gavia immer</i>	?	x	x		
Yellow-billed Loon <i>Gavia adamsii</i>	x	x			x
Northern Fulmar <i>Fulmarus glacialis</i>	x	x	x	x	x
Red-necked Grebe <i>Podiceps grisegena</i>	x	x	x		x
Horned Grebe <i>Podiceps auritus</i>		x			x
Great Cormorant <i>Phalacrocorax carbo</i>			x		
Pelagic Cormorant <i>Phalacrocorax pelagicus</i>	x				x
Merlin <i>Falco columbarius</i>	x	x			x
Gyr Falcon <i>Falco rusticolus</i>	x	x	x		x
Peregrine Falcon <i>Falco peregrinus</i>	x	x	x		x
White-tailed Eagle <i>Haliaeetus albicilla</i>			x		x*(a)
Bald Eagle <i>Haliaeetus leucocephalus</i>		x			
Northern Harrier <i>Circus cyaneus</i>	x	x			x*(a)
Pallid Harrier <i>Circus macrourus</i>					x*(a)
Roughleg <i>Buteo lagopus</i>	x	x			x
Golden Eagle <i>Aquila chrysaetos</i>	x	x			x*(a)
Siberian Crane <i>Grus leucogeranus</i>					x
Sandhill Crane <i>Grus canadensis</i>	x	x			x
European Golden Plover <i>Pluvialis apricaria</i>			x		x
American Golden Plover <i>Pluvialis dominica</i>	x	x	x		
Pacific Golden Plover <i>Pluvialis fulva</i>	x	x			x
Grey Plover <i>Pluvialis squatarola</i>	x	x	x		x
Common Ringed Plover <i>Charadrius hiaticula</i>		x	x	x	x
Semipalmated Plover <i>Charadrius semipalmatus</i>	x	x			x
Lesser Sand Plover <i>Charadrius mongolus</i>					x*
Eurasian Dotterel <i>Charadrius morinellus</i>	x				x
Jack Snipe <i>Limnocyptes minimus</i>					x
Pin-tailed Snipe <i>Gallinago stenura</i>					x
Great Snipe <i>Gallinago media</i>					x*
Common Snipe <i>Gallinago gallinago</i>					x
Wilson's Snipe <i>Gallinago delicata</i>	x	x			
Long-billed Dowitcher <i>Limnodromus scolopaceus</i>	x	x			x
Hudsonian Godwit <i>Limosa haemastica</i>		x			
Bar-tailed Godwit <i>Limosa lapponica</i>	x				x
Whimbrel <i>Numenius phaeopus</i>	x	x	x		x
Bristle-thighed Curlew <i>Numenius tahitiensis</i>	x(d)				
Spotted Redshank <i>Tringa erythropus</i>					x
Lesser Yellowlegs <i>Tringa flavipes</i>	x	x			
Solitary Sandpiper <i>Tringa solitaria</i>	x	?			
Wood Sandpiper <i>Tringa glareola</i>					x
Terek Sandpiper <i>Xenus cinerea</i>					x©
Spotted Sandpiper <i>Actitis macularius</i>	x	x			
Upland Sandpiper <i>Bartramia longicauda</i>	x				
Grey-tailed Tattler <i>Heteroscelus brevipes</i>					x*
Wandering Tattler <i>Heteroscelus incanus</i>	x	x			x*
Ruddy Turnstone <i>Arenaria interpres</i>	x	x	x	x	x
Black Turnstone <i>Arenaria melanocephala</i>	x				
Surfbird <i>Aphriza virgata</i>	x				
Great Knot <i>Calidris tenuirostris</i>					x
Red Knot <i>Calidris canutus</i>	x	x	x	x	x
Sanderling <i>Calidris alba</i>		x	x	x	x
Semipalmated Sandpiper <i>Calidris pusilla</i>	x	x			x
Western Sandpiper <i>Calidris mauri</i>	x	x			x
Red-necked Stint <i>Calidris ruficollis</i>	x				x
Little Stint <i>Calidris minuta</i>					x

Temminck's Stint <i>Calidris temminckii</i>						x
Least Sandpiper <i>Calidris minutilla</i>	x	x				
White-rumped Sandpiper <i>Calidris fuscicollis</i>	x	x				
Baird's Sandpiper <i>Calidris bairdii</i>	x	x	x			x
Pectoral Sandpiper <i>Calidris melanotos</i>	x	x	x			x
Sharp-tailed Sandpiper <i>Calidris acuminata</i>						x
Curlew Sandpiper <i>Calidris ferruginea</i>	x					x
Purple Sandpiper <i>Calidris maritima</i>		x	x	x		x
Rock Sandpiper <i>Calidris ptilocnemis</i>	x(d)					x
Dunlin <i>Calidris alpina</i>	x	x	x	x		x
Stilt Sandpiper <i>Calidris himantopus</i>	x	x				
Spoon-billed Sandpiper <i>Eurymorhynchus pygmeus</i>						x
Broad-billed Sandpiper <i>Limicola falcinellus</i>						x
Buff-breasted Sandpiper <i>Tryngites subruficollis</i>	x	x				x
Ruff <i>Philomachus pugnax</i>						x
Red-necked Phalarope <i>Phalaropus lobatus</i>	x	x				x
Red Phalarope <i>Phalaropus fulicarius</i>	x	x	x	x		x
Mew Gull <i>Larus canus</i>	x	x				x*
Great Black-backed Gull <i>Larus marinus</i>		x	x	x		x
Glaucous Gull <i>Larus hyperboreus</i>	x	x	x	x		x
Iceland Gull <i>Larus glaucooides</i>		x	x			x
Thayer's Gull <i>Larus thayeri</i>		x	x			
Herring Gull <i>Larus argentatus</i>		x	x			x
Lesser Black-backed Gull <i>Larus fuscus</i>			x			x
Common Black-headed Gull <i>Larus ridibundus</i>			x			
Ivory Gull <i>Pagophila eburnea</i>		x	x	x		x
Ross's Gull <i>Rhodostethia rosea</i>		x	x	x		x
Sabine's Gull <i>Xema sabini</i>	x	x	x	x		x
Black-legged Kittiwake <i>Rissa tridactyla</i>	x	x	x	x		x
Arctic Tern <i>Sterna paradisaea</i>	x	x	x	x		x
Aleutian Tern <i>Sterna aleutica</i>	x(d)					
Great Skua <i>Stercorarius skua</i>				x		
Pomarine Skua <i>Stercorarius pomarinus</i>	x	x				x
Parasitic Jaeger <i>Stercorarius parasiticus</i>	x	x	x	x		x
Long-tailed Jaeger <i>Stercorarius longicaudus</i>	x	x	x	x		x
Little Auk <i>Alle alle</i>		x	x	x		x
Thick-billed Murre <i>Uria lomvia</i>	x	x	x	x		x
Common Murre <i>Uria aalge</i>	x	x	x			x
Razorbill <i>Alca torda</i>		x	x	x		
Black Guillemot <i>Cephus grylle</i>	x	x	x	x		x
Pigeon Guillemot <i>Cephus columba</i>	x					
Kittlitz's Murrelet <i>Brachyramphus brevirostris</i>	x(d)					x(b)
Parakeet Auklet <i>Aethia psittacula</i>						x(b)
Least Auklet <i>Aethia pusilla</i>	x(d)					x(b)
Crested Auklet <i>Aethia cristatella</i>						x(b)
Atlantic Puffin <i>Fratercula arctica</i>			x	x		x
Horned Puffin <i>Fratercula corniculata</i>	x					x
Tufted Puffin <i>Fratercula cirrhata</i>	x					x
Snowy Owl <i>Nyctea scandiaca</i>	x	x	x	x		x
Short-eared Owl <i>Asio flammeus</i>	x	x				x
Northern Flicker <i>Colaptes aurata</i>	x					
Say's Phoebe <i>Sayornis saya</i>	x	x				
Alder Flycatcher <i>Empidonax alnorum</i>	x(d)					
Great Grey Shrike <i>Lanius excubitor</i>	x	x				x⊙
Eurasian Magpie <i>Pica pica</i>						x
Carrion Crow <i>Corvus corone</i>						x(b)
Northern Raven <i>Corvus corax</i>	x	x	x			x
Sand Martin <i>Riparia riparia</i>	x(d)					x
American Cliff Swallow <i>Petrochelidon pyrrhonota</i>	x					

Horned Lark <i>Eromophila alpestris</i>	x	x	x		x
Sedge Warbler <i>Acrocephalus schoenobaenus</i>					x*(a)
Arctic Warbler <i>Phylloscopus borealis</i>	x				x
Willow Warbler <i>Phylloscopus trochilus</i>					x
Common Chiffchaff <i>Phylloscopus collybita</i>					x*(a)
Grey-cheeked Thrush <i>Catharus minimus</i>	x	x			x
Naumann's Thrush <i>Turdus naumanni</i>					x
Fieldfare <i>Turdus pilaris</i>				x	x*(a)
Redwing <i>Turdus iliacus</i>				x	x(a)
American Robin <i>Turdus migratorius</i>	x	x			
Bluethroat <i>Luscinia svecica</i>	x				x
Eurasian Stone Chat <i>Saxicola torquatus</i>					x*(a)
Northern Wheatear <i>Oenanthe oenanthe</i>	x	x	x		x
American Dipper <i>Cinclus mexicanus</i>	x	x			
Eurasian Tree Sparrow <i>Passer montanus</i>					x*(e)
House Sparrow <i>Passer domesticus</i>					x(e)
Siberian Accentor <i>Prunella montanella</i>					x*(a)
Western Yellow Wagtail <i>Motacilla flava</i>	x	x			x
Citrine Wagtail <i>Motacilla citreola</i>					x
White Wagtail <i>Motacilla alba</i>	x(d)			x	x
Meadow Pipit <i>Anthus pratensis</i>				x	x
Pechora Pipit <i>Anthus gustavi</i>					x
Red-throated Pipit <i>Anthus cervinus</i>	x				x
Buff-bellied Pipit <i>Anthus rubescens</i>	x	x	x		x
Common Redpoll <i>Carduelis flammeus</i>	x	x	x		x
Arctic Redpoll <i>Carduelis hornemanni</i>	x	x	x		x
Asian Rosy Finch <i>Leucosticte arctoa</i>	x(d)				x
Grey-crowned Rosy Finch <i>Leucosticte tephrocotis</i>	x				
Orange-crowned Warbler <i>Vermivora celata</i>	x(d)				
Blackpoll Warbler <i>Dendroica striata</i>	x(d)				
Yellow Warbler <i>Dendroica petechia</i>	x	x			
Northern Waterthrush <i>Seiurus noveboracensis</i>	x(d)	x			
Wilson's Warbler <i>Wilsonia pusilla</i>	x	x			
Rusty Blackbird <i>Euphagus carolinus</i>	x(d)	x			
Little Bunting <i>Emberiza pusilla</i>					x
Pallas's Reed Bunting <i>Emberiza pallasi</i>					x
Common Reed Bunting <i>Emberiza schoeniculus</i>					x*
Lapland Longspur <i>Calcarius lapponicus</i>	x	x	x		x
Smith's Longspur <i>Calcarius pictus</i>	x	x			
Snow Bunting <i>Plectrophenax nivalis</i>	x	x	x	x	x
Fox Sparrow <i>Passerella iliaca</i>	x	x			
Lincoln's Sparrow <i>Melospiza lincolni</i>	x(d)				
Harris's Sparrow <i>Zonotrichia querula</i>		x(a)			
White-crowned Sparrow <i>Zonotrichia leucophrys</i>	x	x			
Savannah Sparrow <i>Passerculus sandwichensis</i>	x	x			?
American Tree Sparrow <i>Spizella arborea</i>	x	x			
203 species	129	112	72	33	147

* Of marginal occurrence in the Arctic

(a) Breeds in the extreme south of the tundra zone

(b) Breeds on the Chukotski Peninsula

(c) Extends into the tundra zone only along wooded valleys, particularly river valleys

(d) Breeds on the Seward Peninsula

(e) Associated with human settlements

(22 species)

(13 species)

(4 species)

(3 species)

(17 species)

(2 species)